Chapter 8

Epilogue

8.1 Summary of Test Results

The initial Lifting Body research flight test program was aimed at the development of horizontal landing techniques for a class of entry configurations which would use ablation technology for thermal protection during entry (M2-F3, HL-10, X-24A). Aerodynamic refinements which produced acceptable low speed L/D's suitable for approach and landing were demonstrated . Flight control difficulties for these short-coupled and roll-prone vehicles were successfully overcome. Following flight at supersonic speeds, each of the three heavy-weight lifting bodies were successfully landed. Adequate transonic stability and controllability were thereby demonstrated. Only the X-24A had a pilot canopy configuration with suitable forward visibility at landing for a mission vehicle.

A successful and highly repeatable approach and landing technique was developed for unpowered, low L/D vehicles. The critical phases of this technique were identified. In spite of the high drag of these vehicles, some type of speed brake was required to achieve the precise, pre-flare energy conditions needed for accurate landings.

The fourth configuration - the X-24B - must be considered a second-generation lifting body. It could use either metallic or ceramic insulation for thermal protection and could accomplish considerably more maneuvering during entry than the earlier configurations. The low-speed handling qualities were improved over the earlier vehicles. Following a supersonic flight, the X-24B successfully landed on a concrete runway, and thereby demonstrated an additional aspect of operational flexibility.

While the lifting body flight test data were being gathered, the effects of ablation surface roughness on low speed drag were also being assembled. As mentioned in Chapter 6, full scale wind tunnel tests of the X-24A with a simulated rough ablator surface showed a reduction in L/D of 20 percent (Reference Pyle, 1969). Tests at WPAFB on an 8 percent model of the X-24A showed similar results (Reference Ash, Vol. II, 1972). Flight tests of the X-15A-2, which used a thin ablative coating, showed a reduction in L/D of about 15 percent after a relatively mild exposure to the aerodynamic heating environment (Ref Ash, Vol. II, 1972). Comparison tests of two PRIME vehicles, one before flight and one after flight, showed a 30 percent reduction in L/D (Reference Spisak).

These effects were also accompanied by reductions in stability which would obviously be quite detrimental to the handling qualities. It must be concluded that the first three lifting body vehicles, as originally conceived, would probably not have been land-able following an entry with a normally-ablated thermal protection system. [1]

8.2 Implications for Space Shuttle

These flight test programs represent some, but certainly not all, of the research flight testing that led to the Space Shuttle Orbiter as the first successful, manned lifting-entry vehicle. [2] The Orbiter is a winged vehicle and bears more resemblance to the X-20 than to any of the lifting bodies. Landing the Orbiter utilizes unpowered landing techniques that were originally developed for the X-15 program, and later adapted to the lifting bodies. The continued successful ability of the AF/NASA team to accurately land all of these vehicles without power caused the Space Shuttle design team to reassess their need for a landing engine. John Manke personally made over thirty flights in the NASA 2-seat F-104's or T-38's demonstrating to various astronauts, engineers, managers and politicians the simulated lifting body approach and landing patterns. The Space Shuttle design team finally accepted the unpowered landing technique which had been developed and validated by the AF/NASA flight test team at Edwards, thus saving a considerable amount of weight and complexity in the Orbiter.

The low-speed L/D's of each configuration are compared at the same airspeeds [3] in Figure 8-1. A similar comparison of the gear-down configurations is shown in Figure 8-2. The predicted L/D of the X-20 is not shown since it was never flown, but the predicted values were almost identical to those of the X-24B. Notice that the L/D of the "winged" Orbiter is closer to the L/D of the "winged" X-15 than to any of the lifting bodies.

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[1] Further study and wind tunnel testing were required to identify the true cause of these effects. It is likely that the judicious use of smooth, high temperature materials (such as carbon-carbon) placed in critical locations on the vehicle would have substantially improved the low speed characteristics after entry.

[2] The ASSET and PRIME flight test programs have already been mentioned in the text. Several other test programs were flown using jet-powered aircraft simulating low L/D vehicles. These programs demonstrated large-airplane low L/D approaches, instrument approaches to 1000 feet altitude, night landing techniques as well as telescopes and fiber optics for reduced visibility (Reference Schofield et al, 1970).

[3] L/D is plotted against the lift coefficient (CL) divided by the wing loading (W/S). This parameter allows vehicles of different size and configuration to be compared at the same equivalent airspeed.

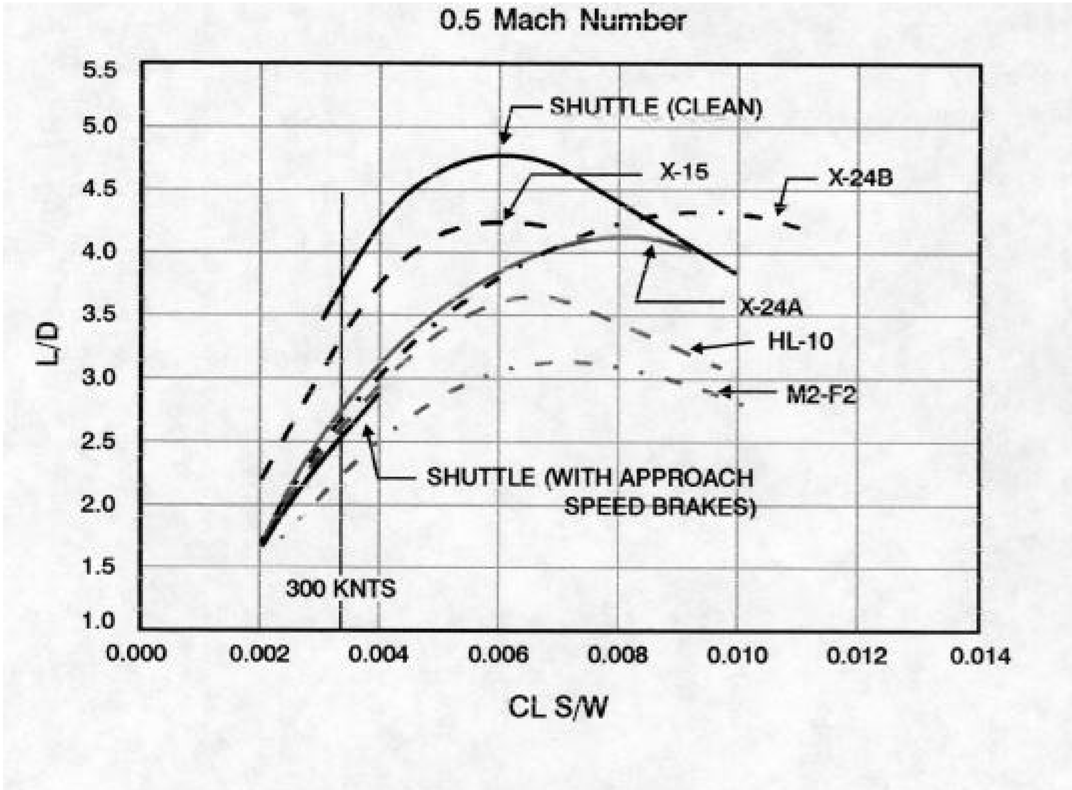

Figure 8-1: L/D Comparisons, Gear Up

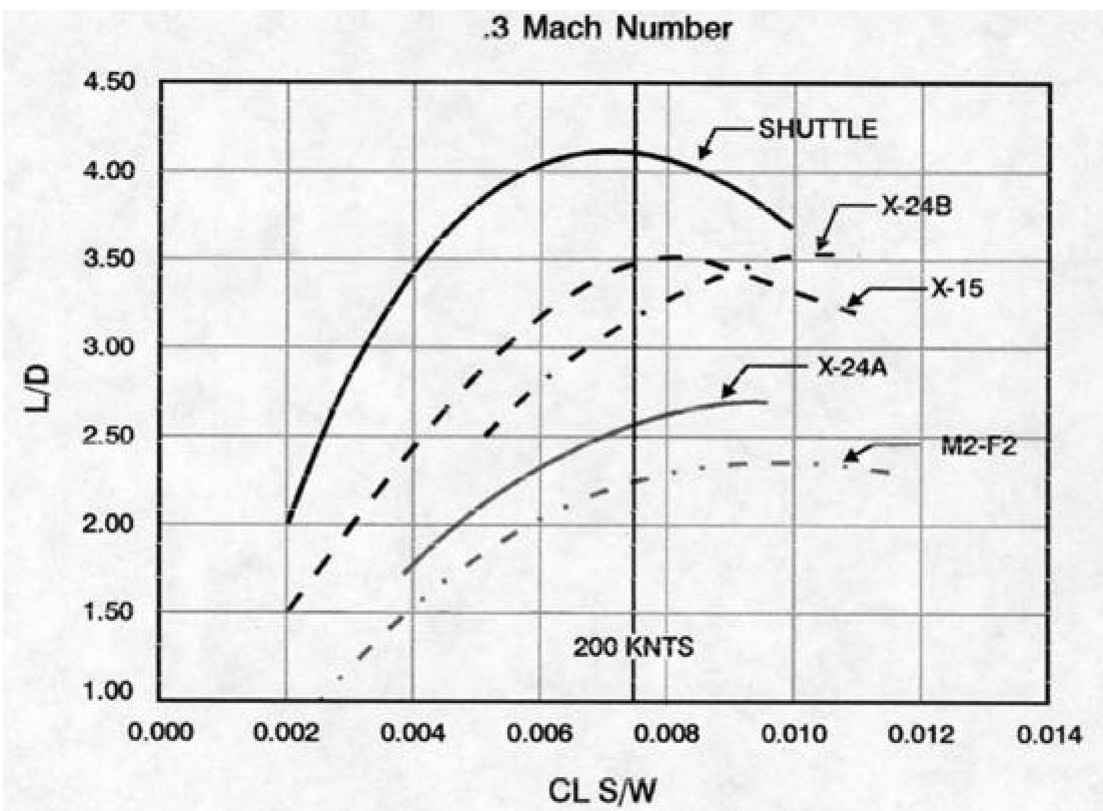

Figure 8-2: L/D Comparisons, Gear Down

The most significant technology contribution to the success of the Space Shuttle Orbiter came from the laboratory, not the Lifting Body program. Pioneered by Lockheed and fostered by NASA Ames Research Center, it was the successful development of a new thermal protection concept. The light weight ceramic tiles and the associated bonding attachment methods were truly the enabling technology for lifting entry. As John Becker stated (Reference Hallion, Vol. I, p. 444),"..the Shuttle enjoys a thermal protection system far more effective and more durable than the metallic radiative structure of Dyna Soar. In essence its light weight ceramic blocks are the 'unobtainium' that we could only dream of in the '50s and early '60s."

The Air Force originally planned to launch the Space Shuttles into polar orbit from Vandenberg AFB in California. In order to return to the launch site during a once-around-abort, the Orbiter needed a cross-range capability of 1200 nautical miles. Throughout the development of the Space Shuttle, the DOD insisted on retention of this 1200-nautical-mile cross-range capability. Although it has never been demonstrated, transient tests of the Orbiter during actual entry have shown that the thermal protection system (as currently configured) is adequate for this high cross-range entry (Reference Richardson, et al, 1983). The current Shuttle mission does not require high cross-range, and the entry L/D used by the Orbiter is about 1.0, similar to that available with the M2, HL-10 and X-24A configurations. Although the technology and hardware are now available, it is significant that a truly high L/D entry has yet to be flown with any vehicle.

8.3 The Future of Lifting Bodies

The light-weight ceramic tile technology developed for the Space Shuttle opens the door to ALL of the lifting entry concepts, including the lifting bodies described in this report. Highly maneuverable entries with over 2400 miles cross-range are possible with X-24B-like configurations. For non-military entry missions (space station return, space-rescue, etc.), where payload fraction is more important than cross-range, the entire spectrum of lifting bodies with entry L/D's of 1.0 to 1.4 are also now feasible (Figure 8-3).

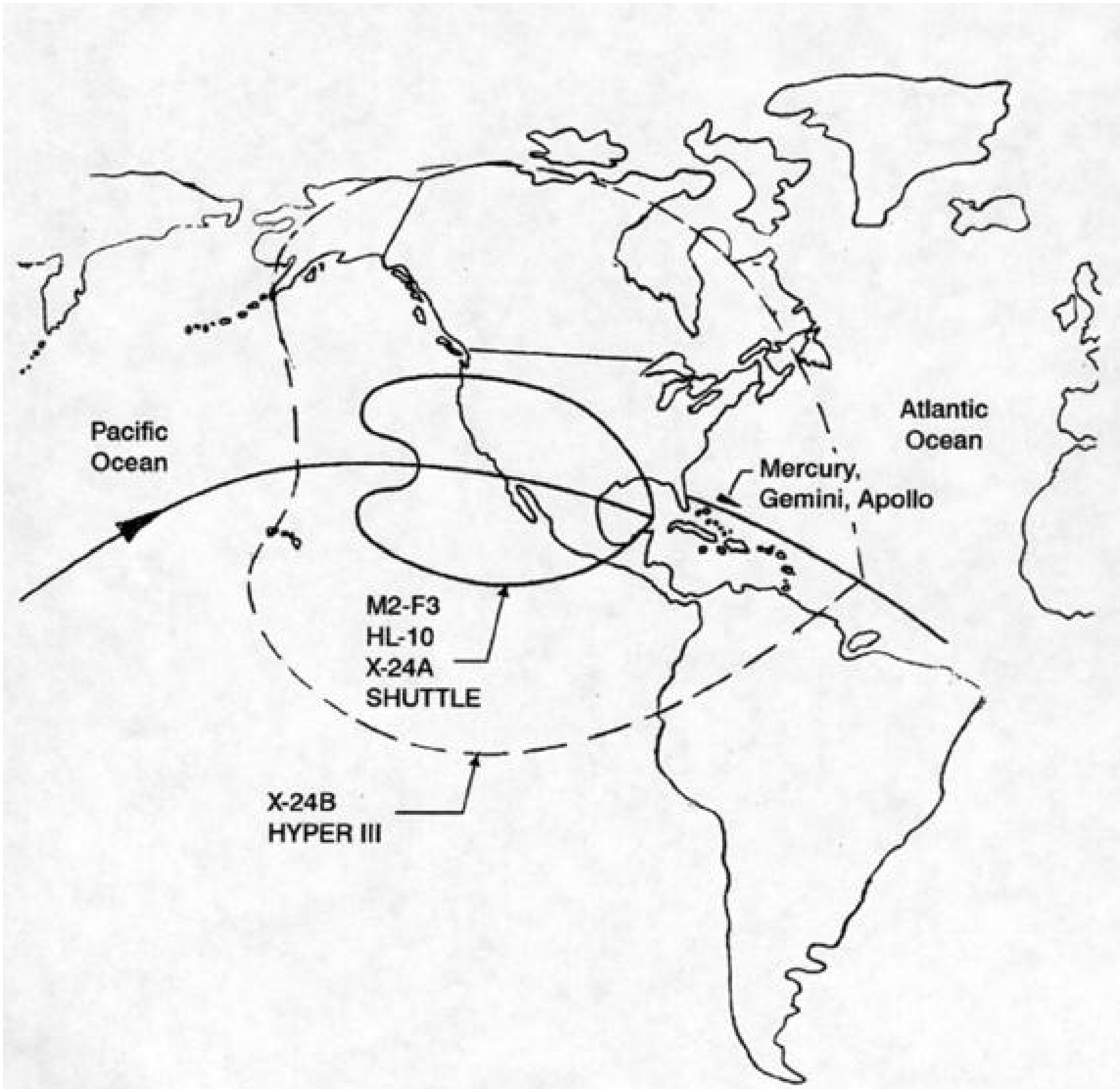

Figure 8-3: Orbital Entry Footprints for Lifting Bodies and Other Vehicles

8.4 Other Benefits

The Lifting Body program highlighted another important attribute not related to technology: the ability of a small team of dedicated individuals to achieve great accomplishments in a short time and with limited resources, provided they are not encumbered by political or bureaucratic constraints. This is especially significant when one realizes that two-thirds of this team were within the Federal Government (NASA and AF). Team members were allowed to function in a manner which was outside the typical procurement practices, and, for the most part, were allowed to make major decisions at the working level throughout the program. This highly productive environment was created by the outstanding leadership of Paul Bikle, the Director of NASA Flight Research Center with full cooperation of several AFFTC Commanders.

The rocket-powered research aircraft programs conducted by joint AF/NASA teams over the years have also made significant contributions in the area of new flight test methods. By their nature, the flights of these vehicles are very transient. Stabilized flight conditions (speed and altitude) cannot be sustained for longer than a few seconds. The flight test engineers supporting these programs developed new methods of transient testing and analysis involving short control pulses and control sweeps. The value of these new methods, in terms of data return per minute of test time, were obvious to the jet-airplane testing community, and many of these methods are now employed in the routine testing of conventional airplanes.

The value of one-of-a-kind research airplanes continues to be a controversial subject. Advocates think that the value of periodically constructing and testing new hardware at relatively low cost will lead to advancements in technology even though the particular subject of the research may not prove fruitful. Charlie Feltz, Chief Engineer for North American on the X-15 program, stated that well over 50 percent of the research value from the X-15 program occurred BEFORE the first flight. He was referring to (1) new manufacturing methods for Inconel and Titanium, (2) new subsystems designed for operation at 0 g, (3) a new man-rated rocket engine, (4) the overall systems integration task, and a host of other new design and manufacturing technologies that had to be developed before flight could even be attempted. Opponents argue that the research would be better focused on the development of true, mission-capable vehicles even though technological failure would be very costly.

Frequent low-cost testing of one-of-a-kind vehicles allows the country to retain a team of researchers who can provide continuity in technological advancement and changing operational concepts. The major development of a new mission-capable vehicle is often separated from its predecessor by 20 to 50 years and the technology transfer is often a major problem. The AF/NASA team at Edwards provided this technical continuity for over 30 years and provided a major portion of the operational concepts, technical requirements and personnel to the Space Shuttle program.

The Lifting Body program proved to be a good application of the research airplane principle: the use of low cost vehicles in a relatively high-risk environment. The success of the Lifting Body program set the stage not only for the Space Shuttle, but also for an entire family of future lifting entry vehicles.